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NUTRITIONALLY FORTIFIED FRUITCAKE (THERMOPROCESSED, FLEXIBLY PACKAGED) DEVELOPED FOR SHUTTLE FLIGHT USE

M. V. Klicka

D. E. Sherman

B. Atwood

W. Swantak

K. M. Thompson

M. T. Branagan

June 1981

UNITED STATES ARMY
NATICK RESEARCH and DEVELOPMENT LABORATORIES
NATICK, MASSACHUSETTS 01760

Food Engineering Laboratory

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A storage study on fruitcake was conducted at NLABS to determine if the fortified fruitcake would retain its acceptability and nutritional value in extended storage. The thermoprocessed flexibly packaged fortified fruitcake was to be nutritionally adequate for use as a NASA contingency ration. Vitamins (A, C, thiamin, niacin, riboflavin, pyridoxine, B_{12}), calcium and magnesium were added to meet 100 percent of the 1968 Recommanded Daily Allowance (RDA) for males 22–35 years of age. All fruitcakes were storad for three years

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20. Abstract (cont'd)

at 4° and 21°C and one year at 38°C. Fortified fruitcake was found to be acceptable. It retained nutritional quality during storage and met NASA's requirements for major nutrients.

SUMMARY

NASA asked Natick Laboratories to develop a contingency ration that would meet and retain 100 percent of the Recommended Daily Allowance (RDA) and maintain consumer acceptability under ambient storage conditions for three years. NASA chose flexibly packaged fruitcake, a single food, as the approach to this ration. The desired fruitcake was to be nutritionally complete, meeting the 1968 RDA for males 22–35 years of age (700 grams supplying 2800 calories, 65 grams protein, nine vitamins and at least four minerals). The fruitcake was fortified with vitamins (A, C, thiamin, riboflavin, niacin, pyridoxine and B_{12}), calcium and magnesium.

Three hundred ninety fortified and 388 unfortified 170-grams portions of fruitcake were prepared and thermoprocessed in polyolefin-foil-polyester pouches. Respective products were each divided equally into three lots and stored for three years at 4°C and 21°C and one year at 38°C. Initial, 3, 6, 9, 12, 16, 24, 30, and 36-month withdrawals were made for nutrient analyses and consumer acceptance tests. Initial analyses (in duplicate) were performed for proximate, mineral, fatty acid and vitamin content. Stored samples were analyzed for moisture and vitamin content only.

Each acceptance test consisted of 36 untrained consumers selected at random from the 400-member NLABS Food Acceptance Panel. Samples of both fruitcakes were rated on a nine-point hedonic scale. Both fruitcakes were rated as acceptable, retaining their nutrient quality throughout storage. The fortified fruitcake met NASA's requirements for major nutrients. There was no difference between the ratings for fortified and unfortified fruitcakes. Initially the fruitcakes received "like moderately" ratings; neither product dropped below the "neither like nor dislike" mid-point throughout the storage study.

PREFACE

The research described in this report was performed for the National Aeronautics and Space Administration (NASA) under MIPR No. DPRT–9371A.

Development of a single-food contingency ration which would meet NASA requirements for storage stability, consumer acceptability and nutrition was a unique challenge. Fortunately, US Army Natick Research and Development Laboratories (NLABS) scientists had successfully developed a family of flexibly packaged thermoprocessed cakes for use in the Meal, Ready-to-Eat, Individual MRE), a new combat ration. Capitalizing on this accomplishment, NLABS was able to expedite the development of a fruitcake suitable for contingency use.

Astronaut acceptance of this special nutrient fortified fruitcake had been confirmed on the Apollo 17 Flight, and therefore was included in the Skylab food supply as a contingency food. As a further testimony to its acceptability, NASA approved the consumption of some of this cake on Christmas Day 1973 as a holiday treat. Fruitcake is also on the OFT Shuttle Flight menus. This report describes the results of a three-year storage study on fortified and unfortified fruitcake.

The work described in this report was performed in-house at NLABS except that all nutrient analyses (proximate, mineral, fatty acid and vitamin) were performed by Shankman Laboratories, Los Angeles, California under contract numbers DAAK17–72–D–0002 and DAAK03–75–C–0051.

The authors wish to gratefully acknowledge the contributions of Mrs. Nancy Kelley, Mr. Henry Russell, Mr. Henry Morgan, Mr. Gerald Schulz, in the production and packaging of the fruitcake; Mrs. Miriam Thomas and Dr. Kenneth Hall for preparation of the vitamin premix; Mr. Leon Klarman and Dr. Edward Ross for their data analysis support; Ms. Christine Kubik for her assistance in preparation of tables and Mrs. Joyce Barrett, Mrs. Barbara Leston and Ms. Dorothy Aspinwall for their dedicated typing support.

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INTRODUCTION

In 1968, the National Aeronautics and Space Administration (NASA) asked the US Army Natick Research and Development Laboratories (NLABS) to develop a contingency ration which would remain acceptable throughout three years ambient storage (21°C), withstand short time exposure to temperatures ranging from −18°C to 38°C, and have the least possible volume. A thermoprocessed flexibly packaged fruitcake,[1] one of the approaches suggested by NLABS, was acceptable to NASA. NASA requested, in 1972, that a nutritionally complete fruitcake be developed as an initial shuttle flight ration, to meet the Recommended Dietary Allowances (RDA) for males 22–35 years of age (2800 calories, 65 grams of protein and variable requirements for nine different vitamins and at least four minerals).[2] Analysis of the fruitcake developed by NLABS showed that 700 grams would supply 2800 calories, but required fortification with vitamins and minerals as well as doubling of the protein content.

NLABS' first approach was to identify appropriate protein sources for fortification. Soy sources were selected over the other available protein sources (eggs, non-fat milk, wheat gluten, etc.) to increase the protein content of the fruitcake. The use of soy concentrates and flours in proportions greater than 50 percent substitution of flour resulted in unacceptable products. When defatted soy flour (52.5 percent protein) was substituted for one-half of the cake flour in the Mason et al. formula, the product was considered acceptable by a technological panel. The resulting percent protein content of the product containing one-half soy flour and one-half cake flour was slightly low, being 7.5 percent instead of 9.3 percent (RDA) of total calories. Later, NASA determined that the protein content should remain at 7 to 8 percent of total calories to assure suitability for consumption as a contingency food, under conditions of limited water intake. Several other soy fortified cakes, including cherry nut and chocolate nut, were furnished to NASA for evaluation and comment. NASA indicated interest in the fruitcake sample only.

In 1972, NASA selected a nutrient fortified fruitcake for the Apollo 17 crew and requested: (1) sufficient product to meet Apollo 17 needs, (2) a space food prototype production guide (Appendix A), and (3) precise nutrient data. No vitamin fortification was prescribed in the production guide.

[1] O.E. Mason, G.L. Schulz, P.H. Katz, J.W. Szczeblowski and D.E. Wescott. "Development of Flexibly-Packaged, Thermally-Processed Bakery Products," Activities Report, Vol. 17, p. 145–151, Fall 1965.

[2] "Recommended Dietary Allowances". Food and Nutrition Board, National Academy of Sciences-National Research Council. Seventh Revised Edition, 1968.

Due to tha lack of information on the losses of vitamins during production, the amounts of vitamins and minerals required efter processing were determined and added in doubled amounts to enticipata tha Apollo 17 requirement. Industry wes contacted and confirmed tha retionale for these initial levels of fortification. Nutritional analysis of tha Apollo 17 product revealed that:

a. The protein leval was adequate (7 to 8 percent of total calories).

b. Additional magnasium was required.

c. Racovery of the vitamin A appeared poor. (It was latar discovered that only 1/10 of the calculated amount of vitamin had been added.)

d. Ascorbic acid and thiamin levels were adequate to cover processing losses; h ·er, both needed to be increased to assure adequate retention during storage for a year ; 8°C.

e. Water activity of the Apollo 17 product was 0.70; pH was 4.7.

It was expected that nutrient ratention (dependent variable) would follow a d d trend with incraasing temperatures and storage time (independent variablas), with the ..test losses in ascorbic acid (vitamin C) and thiamin. The basic intent was fortification of fruitcake to maintain nutrient retention of the RDA levels for 36 months at 21°C and 6 months storage at 38°C. Tha following hypothesis is thus stated conclusivaly: As storage time and temperature incraases, nutrient retention and consumer acceptance of fortified fruitcake decreases.

EXPERIMENTAL METHODS AND PROCEDURES

A storage study was initiated on fruitcake produced in accordance with the same formula used for the Apollo 17 product, with nutrient levals increased as follows: Vitamin A was increased four-fold; thiamin was doubled; ascorbic acid was increased four-fold. An unfortified (control) fruitcake was also included in the study.

MATERIALS

Tha ingredients used in this study wera locally purchased. Section 3 of Appendix A lists the ingredients used and the formula for the unfortified fruitcake on a percent by weight basis. Three batches of 22.7-kg (50-lb) unfortified and fortified fruitcake were produced. The products were the same except for the addition of the following nutrients (per 22.7-kg batch) to the fortified product:

Thiamin mononitrate	200	mg
Riboflavin	150	mg
Niacin	1.5	mg
Pyridoxine hydrochloride	150	mg
Vitamin A palmitate (250,000 IU/gm)	5.24	g
Ascorbic Acid (1)	12.3	g
Vitamin B_{12} (0.1% titration)	454	mg
Magnesium sulfate	15	g
Calcium lactate	15	g

Special Mixing Procedures for Vitamin-Fortified Fruitcake

The vitamin premix was prepared by mixing 1.8 kg of granulated sugar with four times the amount of all vitamins and magnesium sulfate required for a 22.7-kg (50-lb) batch of fruitcake. Each vitamin was mixed, using a spatula, with a small amount of sugar, then the remaining sugar was added using a Blakeslee Mixer on low speed. The premix was refrigerated until used. One-fourth of the premix, 0.57-kg (1.25-lb), was used in each fortified batch of fruitcake in lieu of one pound of the sugar specified in the basic formula. Each batch of the product was prepared and pouches ware filled with 6 oz. of product, in accordance with the Space Food Prototype Production Guide included as Appendix A. Vacuum packaging and pasteurization were not required for the storage study.

Storage

Nutrient fortified and unfortified lots of fruitcake were stored for a total of three years at 4°C and 21°C and for one year at 38°C. Table 1 indicates the withdrawal periods for nutrient and sensory analyses.

Table 1. Plan of Withdrawal for Nutritional and Sensory Analyses of Fortified and Unfortified Fruitcake

Storage Temperature, °C	Months in Storage								
	Initial	3	6	9	12	18	24	30	36
4	N/S	N	N	N	N	N	N/S	N/S	N/S
21		N	N/S	N/S	N/S	N/S	N/S	N/S	N/S
38		N/S	N/S	N/S	N/S				

N = Nutritional Analyses, S = Sensory Analyses

Sensory Analyses

For each acceptance test, 36 untrained consumers were selected at random from the 400 members of NLABS Food Acceptance Taste Panel. Fortified and unfortified fruitcake samples labeled "Fruitcake" were independently presented in random combinations at each session to be rated on a nine-point hedonic scale.[3] Sample serving size was approximately 28 grams (1 oz), and was served at room temperature in the NLABS acceptance testing area which is designed to minimize noise and distraction during testing. Means and standard deviations were obtained on all product ratings.

[3]D.R. Peryam and F.J. Pilgrim. Hedonic Scale Method of Measuring Food Preference. Food Technology, 11 (9), Insert p 9, 1957.

Nutrient Analyses

Samples withdrawn for nutrient analyses consisted of a total of 12 pouches, four from each of the three batches of fruitcake. Subsequently, each 12-pouch aggregate was randomly divided into three four-pouch samples. Initial samples were analyzed for proximate, mineral, fatty acids and vitamin content. Stored samples were analyzed for moisture and vitamin content only. Previous experience in analyses of stored products indicated that mineral, proximate and fatty acid contents do not change significantly. All nutrient analyses were performed, in duplicate, by Shankman Laboratories which utilized standard methods specified in the contract.* No analyses for vitamin B_{12}, vitamin E, and folic acid were made as the contract did not include these nutrients. Standard stetistical methods were used in data analyses (ANOVA, regression analysis, and iteratively-reweighted least-squares).[4]

RESULTS AND DISCUSSION

Sensory Analyses – Consumer Acceptance

Table 2 presents the consumer ratings of the fortified and unfortified fruitcake stored at 4°, 21°, and 38°C. The mean and standard deviation with the results of Duncan's multiple range test are given. Figure 1 illustrates consumer ratings, with solid lines representing unfortified and broken lines representing fortified fruitcake. Initially, both the fortified and unfortified product received comparable "like moderately" ratings. At 4°C storage, both the fortified and the unfortified fruitcake remained stable throughout the three-year storage period. The statistical analysis showed that there were no significant differences due to fortification. In fact, throughout the entire storage study there was no significant difference between the ratings for fortified and unfortified samples. All significant differences in ratings were due to time, temperature, or the interaction of these.

During storage at 21°C, samples fluctuated somewhat in acceptability but remained relatively stable throughout the first 18 months of storage. At 24 months, both the fortified and unfortified samples started to decline in acceptability, but at 36 months, ratings were still at the "like slightly" level.

Fortified and unfortified samples stored at 38°C declined in acceptability at the first withdrawal period. Subsequently, the acceptability leveled off and remained in the "neither like nor dislike" to "like slightly" range of acceptability from 6 to 9 months.

*Shankman Laboratories, Los Angeles, CA, Contract Nos. DAAK17–72–D–0002 and DAAK03–75–C–0015. (Letter reports)

[4]D. Coleman, B. Holland, N. Kaden, V. Klema, and S.C. Peters. "A System of Sub-Routines for Iteratively-Reweighted Least-Squares Computations." The Laboratory for Information and Decision Systems. Massachusetts Institute of Technology. Cambridge, MA 02139. December 1977.

Table 2. Consumer Ratings of Fortified and Unfortified Fruitcake Throughout 36 Months Storage (mean ± standard deviation)*

Storage Months	Temp °C	Fortified (F)	Unfortified (U)	Combined (F+U)
0		7.1 ± 1.38	7.2 ± 1.26A	7.17 ± 1.31A
24	4°C	6.5 ± 1.61	7.1 ± 1.33A	6.76 ± 1.50A
30		6.2 ± 1.94	6.0 ± 2.00B	6.12 ± 1.95B
36		**6.7 ± 1.12	**6.6 ± 1.59AB	***B.62 ± 1.30AB
0		7.1 ± 1.38A	7.2 ± 1.26A	7.17 ± 1.31A
3	21°C	6.5 ± 1.61ABC	6.7 ± 1.31ABC	6.57 ± 1.46ABC
6		6.0 ± 1.84CD	6.3 ± 1.51BCD	6.17 ± 1.6BCD
9		6.4 ± 1.13ABC	6.2 ± 1.27CD	6.33 ± 1.20BCD
12		6.9 ± 1.44ABC	7.0 ± 1.11AB	6.94 ± 1.2BAB
18		6.9 ± 1.41AB	7.1 ± 1.33A	7.03 ± 1.36AB
24		6.4 ± 1.4BABC	6.5 ± 1.46ABCD	6.44 ± 1.46BC
30		5.5 ± 2.22D	5.8 ± 1.89D	5.67 ± 2.06D
36		6.2 ± 1.55BCD	6.1 ± 1.91CD	6.18 ± 1.73CD
0		7.1 ± 1.3BA	7.2 ± 1.26A	7.17 ± 1.81A
3	38°C	6.4 ± 1.46B	6.6 ± 1.3BAB	6.46 ± 1.41B
6		5.6 ± 1.82C	5.9 ± 1.71BC	5.76 ± 1.76C
9		5.5 ± 1.36C	5.3 ± 1.70CD	5.42 ± 1.54C
12		5.5 ± 1.96C	5.1 ± 1.88D	5.31 ± 1.92C

*Unlike letters are significantly different at $P \leq 0.05$. Unfortified and fortified columns represent one-way ANOVA while the combined column represents a split-plot ANOVA.

**N = 24

***N = 48

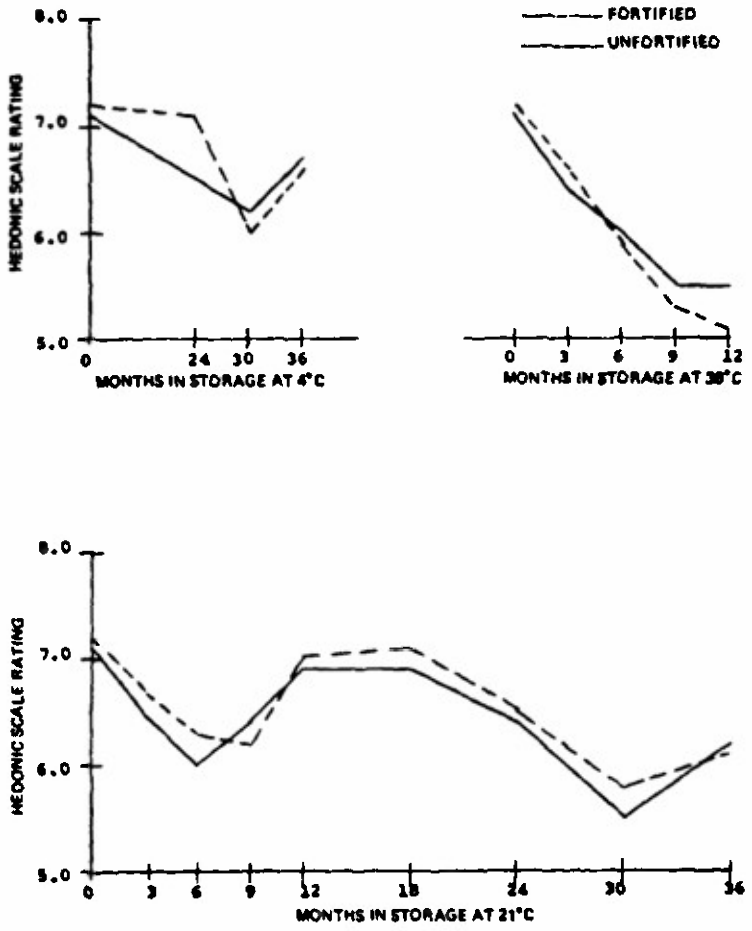


Figure 1. Mean Consumer Acceptance Ratings of Fortified and Unfortified Fruitcake

The results showed that there is no significant difference due to time and temperature at 4°C for three years. However, at 21°C and 38°C there are significant differences due to time, but no significant differences due to fortification. After 9 and 12 months storage, a statistically significant difference in ratings of products stored at 21°C and 38°C occurred indicating a preference for cake stored at 21°C over that stored at 38°C.

Nutrient Analysis

Table 3 summarizes the processing loss of vitamins experienced in the preparation of fruitcake for this study.

Table 3. Vitamin Loss During Processing of Fortified Fruitcake

	Percent
Thiamin	28.4
Riboflavin	16.7
Niacin	3.0
Pyridoxine	28.8
Vitamin A	47.9
Ascorbic Acid	87.0

Proximate and Mineral Analysis

Table 4 summarizes the proximate and mineral data for unfortified and fortified fruitcake. It will be noted that the only statistically significant differences in the data obtained are for calcium and magnesium, the two minerals which were added to the fortified lots of fruitcake.

Multiplication of the mean values of fortified fruitcake (Table 4) by seven shows that the 350 mg RDA for magnesium is met by 700 grams of fruitcake; the 800 mg for calcium is not. This is due to the fact that calcium was inadvertently added at one-half of the planned level. It affirms the need to double the calcium fortification. The RDA requirements for calories (2800) and protein (56 grams) are both met by 700 grams of fortified product. The RDA for phosphorus, iron and iodine are met by 700 grams of both the fortified and unfortified fruitcakes.

Fatty Acid Analyses

Table 5 summarizes the fatty acid data obtained and shows that the fortified and unfortified lots of product were uniform in fatty acid composition.

Vitamin Analyses

Tables 6 and 7 represent the mean and standard deviations of the fruitcake stored at 4°C, 21°C and 38°C for fortified and unfortified samples, respectively, on an as is (wet) basis of approximately 16 percent moisture. The fortified samples (Table 6) met NASA requirements for nutrient stability. Seven hundred grams provides the RDA at the time of production, after 12 months at 38°C and after three years at 4°C and 21°C, with one exception; ascorbic acid was lost in processing (Table 3).

Table 4. Comparison of Proximate and Mineral Content of Fortified and Unfortified Thermoprocessed Fruitcake Per 100 Grams (mean ± standard deviation)*

	Fortified	Unfortified
Moistura, g	16.63 ± 0.30	16.48 ± 0.17
Protein, g	8.10 ± 0.26	7.47 ± 0.32
Fat, g	15.91 ± 0.43	14.33 ± 0.84
Ash, g	1.57 ± 0.09	1.54 ± 0.08
Calcium, mg	83 ± 2.5 [b]	75 ± 2.9 [a]
Phosphorus, mg	147 ± 1.0	145 ± 2.5
Iron, mg	1.9 ± 0.03	2.0 ± 0.09
Sodium, mg	405 ± 22.0	393 ± 41.1
Potassium, mg	339 ± 17.6	333 ± 18.2
Magnesium, mg	61.7 ± 1.53[b]	46.3 ± 1.53[a]
Chloride asNacl, g	0.47 ± 0.02	0.48 ± 0.01
Iodine, mcg	57.0 ± 15.56	51.5 ± 3.54
Fiber, g	2.57 ± 0.25	2.60 ± 0.44
Carbohydrate, g (by difference)	57.79	60.18

*The means followed by different letters are statistically different ($P \leq 0.05$) as determined by the Newman Keul's Multiple Range Test, N = 3 (analyzed in duplicate).

Table 5. Comparison of Fatty Acid Content of Fortified and Unfortified *Thermoprocessed Fruitcake Per 100 Grams* (mean ± standard deviation)

Fatty Acids	Fortified	Unfortified
14:0	0.23 ± 0.06	0.27 ± 0.12*
16:0	10.40 ± 0.40	11.13 ± 0.31
16:1	0.12 ± 0.03	0.13 ± 0.03
18:0	4.73 ± 0.23	5.07 ± 0.25
18:1	63.37 ± 0.32	63.33 ± 0.06
18:2	20.13 ± 0.51	19.27 ± 0.64
18:3	0.83 ± 0.06	0.77 ± 0.06

*An analysis of means shows no difference.

Table 6. Vitamin Content Of Fortified Thermoprocessed *Fruitcake* Stored At 4°, 21°, and 38°C Mean ± Standard Deviation Per 100 Grams Of Product, As Is Basis* (N = 3 Duplicate Analyses)

Months in Storage	Vitamin A IU	Ascorbic Acid mg	Thiamin mg	Riboflavin mg	Niacin mg	Pyridoxine mg
4°C						
Initial	3017 ± 710abc	7 ± 1.7b	0.63 ± 0.038a	0.55 ± 0.029	6.4 ± 0.17abc	0.47 ± 0.010bc
3	3262 ± 123ab	15 ± 1.2a	0.63 ± 0.038a	0.58 ± 0.017	6.9 ± 0.30a	0.63 ± 0.035a
6	2652 ± 413bc	8 ± 2.6b	0.64 ± 0.046a	0.63 ± 0.051	6.4 ± 0.23abc	0.51 ± 0.012b
9	1970 ± 1123c	7 ± 1.5b	0.53 ± 0.040b	0.58 ± 0.072	6.2 ± 0.17bc	0.64 ± 0.026a
12	3046 ± 154abc	5 ± 0.6b	0.55 ± 0.032ab	0.61 ± 0.064	6.4 ± 0.06abc	0.43 ± 0.021c
18	4193 ± 221a	NA	0.55 ± 0.010ab	0.58 ± 0.023	6.5 ± 0.29ab	0.54 ± 0.021b
24	4058 ± 383a	NA	0.55 ± 0.036ab	0.61 ± 0.044	5.9 ± 0.15c	0.65 ± 0.066a
30	3900 ± 409ab	8 ± 1.2b	0.61 ± 0.035ab	0.62 ± 0.046	6.7 ± 0.35ab	0.49 ± 0.021bc
36	3617 ± 104ab	8 ± 0.6b	0.57 ± 0.017ab	0.63 ± 0.076	6.8 ± 0.21ab	0.47 ± 0.035bc
21°C						
Initial	3017 ± 710a	7 ± 1.7ab	0.63 ± 0.037a	0.55 ± 0.029bc	6.4 ± 0.17	0.47 ± 0.010d
3	2908 ± 761a	9 ± 3.5a	0.59 ± 0.044ab	0.60 ± 0.050bc	6.5 ± 0.12	0.66 ± 0.031ab
6	4167 ± 166a	7 ± 1.7ab	0.62 ± 0.015a	0.69 ± 0.050a	6.7 ± 0.21	0.64 ± 0.017abc
9	1838 ± 577b	5 ± 0.6ab	0.51 ± 0.038c	0.63 ± 0.017ab	6.1 ± 0.10	0.59 ± 0.010bc
12	2937 ± 101a	4 ± 0.6b	0.52 ± 0.059bc	0.57 ± 0.050bc	6.8 ± 0.72	0.50 ± 0.021d
18	4268 ± 691a	NA	0.40 ± 0.056d	0.53 ± 0.036bc	6.8 ± 0.26	0.57 ± 0.030c
24	3667 ± 575a	NA	0.47 ± 0.026cd	0.52 ± 0.043bc	6.0 ± 0.26	0.70 ± 0.081a
30	4200 ± 0a	7 ± 0.6ab	0.47 ± 0.021cd	0.57 ± 0.021bc	6.2 ± 0.47	0.44 ± 0.012d
36	3977 ± 239a	4 ± 1.5ab	0.48 ± 0.035cd	0.50 ± 0.055c	6.6 ± 0.26	0.51 ± 0.035d
38°C						
Initial	3017 ± 710ab	7 ± 1.7b	0.63 ± 0.038a	0.55 ± 0.029b	6.4 ± 0.17ab	0.47 ± 0.010
3	2988 ± 192ab	5 ± 1.0b	0.44 ± 0.075b	0.57 ± 0.029b	6.6 ± 0.35a	0.57 ± 0.032
8	3982 ± 262a	5 ± 0.6b	0.35 ± 0.017c	0.66 ± 0.003a	6.2 ± 0.15ab	0.54 ± 0.055
9	2218 ± 647b	6 ± 2.3b	0.26 ± 0.026d	0.53 ± 0.010b	6.0 ± 0.11b	0.50 ± 0.060
12	2750 ± 265b	12 ± 2.6a	0.23 ± 0.011d	0.56 ± 0.055b	6.0 ± 0.10b	0.50 ± 0.040

*An analysis of variance was performed at each temperature. Means followed by different letters are significantly different ($P < 0.05$) as determined by Newman Keuls' Multiple Range Test.

NA = Not Analyzed

Table 7. Vitamin Content of Unfortified Thermoprocessed Fruitcake Stored at 4°, 21° and 38°C Mean ± Standard Deviation Per 100 Grams of Product, As Is Basis[a] (N = 3 Duplicate Analyses)

Months in Storage	Vitamin A IU	Ascorbic Acid mg	Thiamin mg	Riboflavin mg	Niacin mg	Pyridoxine mg
4°C						
Initial	119 ± 42a	3 ± 2.1bc	0.07 ± 0.006ab	0.07 ± 0.021a	0.43 ± 0.058	0.04 ± 0.005bc
3	65 ± 4b	1 ± 1.2c	0.07 ± 0.011b	0.09 ± 0.000a	0.47 ± 0.058	0.05 ± 0.000b
6	33 ± 3bc	9 ± .6a	0.09 ± 0.010a	0.09 ± 0.012a	0.40 ± 0.000	0.05 ± 0.005bc
9	24 ± 4c	4 ± 1.2bc	0.09 ± 0.000a	0.09 ± 0.005a	0.43 ± 0.058	0.07 ± 0.000a
12	31 ± 5bc	1 ± 0.6c	0.08 ± 0.005ab	0.07 ± 0.015a	0.43 ± 0.058	0.02 ± 0.012c
18	67 ± 10b	NA	0.08 ± 0.000ab	0.04 ± 0.005b	0.40 ± 0.000	0.04 ± 0.000cd
24	67 ± 11b	NA	0.08 ± 0.005ab	0.09 ± 0.015a	0.40 ± 0.000	0.05 ± 0.000b
30	55 ± 9bc	5 ± 1.2b	0.08 ± 0.000ab	0.08 ± 0.009a	0.40 ± 0.000	0.03 ± 0.000d
36	40 ± 0bc	4 ± 1.0bc	0.08 ± 0.005ab	0.08 ± 0.006a	0.50 ± 0.000	0.04 ± 0.005cd
21°C						
Initial	119 ± 42a	3 ± 2.1bc	0.07 ± 0.006b	0.07 ± 0.021abc	0.43 ± 0.058	0.04 ± 0.006bc
3	121 ± 31a	1 ± 0.6c	0.09 ± 0.006a	0.08 ± 0.006ab	0.43 ± 0.058	0.08 ± 0.010a
6	44 ± 9ab	6 ± 0.6a	0.09 ± 0.006a	0.09 ± 0.006a	0.47 ± 0.058	0.05 ± 0.010bc
9	28 ± 9b	4 ± 1.2ab	0.08 ± 0.006b	0.07 ± 0.010abc	0.47 ± 0.058	0.06 ± 0.010b
12	29 ± 6b	1 ± 0.6c	0.08 ± 0.000b	0.05 ± 0.006bc	0.40 ± 0.000	0.02 ± 0.000d
18	102 ± 10ab	NA	0.07 ± 0.006b	0.04 ± 0.012c	0.43 ± 0.058	0.04 ± 0.005bc
24	113 ± 56a	NA	0.07 ± 0.006b	0.05 ± 0.010bc	0.50 ± 0.100	0.09 ± 0.015a
30	78 ± 29ab	6 ± 0.0a	0.07 ± 0.000b	0.06 ± 0.012abc	0.47 ± 0.058	0.03 ± 0.000cd
36	83 ± 19ab	3 ± 0.6bc	0.07 ± 0.006b	0.06 ± 0.020bc	0.50 ± 0.000	0.04 ± 0.006cd
38°C						
Initial	119 ± 42a	3 ± 2.1c	0.07 ± 0.005a	0.07 ± 0.021	0.43 ± 0.058	0.04 ± 0.006b
3	71 ± 10b	2 ± 1.2c	0.06 ± 0.000b	0.09 ± 0.015	0.47 ± 0.058	0.05 ± 0.000ab
6	50 ± 13b	6 ± 0.6b	0.05 ± 0.006b	0.08 ± 0.010	0.47 ± 0.058	0.05 ± 0.006b
9	30 ± 6b	5 ± 1.0bc	0.04 ± 0.006c	0.05 ± 0.051	0.40 ± 0.000	0.06 ± 0.010a
12	32 ± 2b	9 ± 1.0a	0.03 ± 0.000c	0.04 ± 0.006	0.40 ± 0.000	0.01 ± 0.000c

[a]An analysis of variance was performed at each temperature. Means followed by different letters are significantly different ($P \leq 0.05$) as determined by Newman Keuls' Multiple Range Test.

NA = Not Analyzed

Table 8. Differences In Vitamin Content Of Fortified and Unfortified Thermoprocessed Fruitcake Stored at 4°, 21° and 38°C Mean ± Standard Deviation Per 100 Grams Of Product, Moisture – Free Basis* (N = 3 Duplicate Analyses)

Months in Storage		Vitamin A IU	Ascorbic Acid mg	Thiamin mg	Riboflavin mg	Niacin mg	Pyridoxine mg
4°C							
3	†	3882 ± 120ab	16 ± 2a	0.69 ± 0.04a	0.59 ± 0.02	7.8 ± 0.4a	0.70 ± 0.04a
6		3129 ± 498bc	-2 ± 4c	0.65 ± 0.06ab	0.65 ± 0.06	7.1 ± 0.3abc	0.55 ± 0.01bc
9		2328 ± 1329c	3 ± 2b	0.53 ± 0.06b	0.59 ± 0.07	6.9 ± 0.3bc	0.68 ± 0.03a
12		3718 ± 152ab	5 ± 2b	0.58 ± 0.06ab	0.65 ± 0.07	7.4 ± 0.2ab	0.50 ± 0.02c
18		4964 ± 235a	NA	0.57 ± 0.01ab	0.65 ± 0.03	7.3 ± 0.3ab	0.61 ± 0.04b
24		4795 ± 453a	NA	0.56 ± 0.05b	0.62 ± 0.05	6.6 ± 0.2c	0.72 ± 0.08a
30		4618 ± 478a	4 ± 1b	0.63 ± 0.04ab	0.64 ± 0.04	7.5 ± 0.4ab	0.54 ± 0.02bc
36		4244 ± 129ab	3 ± 1b	0.58 ± 0.02ab	0.66 ± 0.09	7.4 ± 0.3ab	0.51 ± 0.04c
21°C							
3	–4°†	3882 ± 120ab	16 ± 2a	0.69 ± 0.04a	0.59 ± 0.02bc	7.8 ± 0.4a	0.70 ± 0.04a
3		3329 ± 916b	9 ± 5b	0.59 ± 0.04bc	0.61 ± 0.06bc	7.1 ± 0.2ab	0.69 ± 0.04a
6		4994 ± 165a	1 ± 1c	0.63 ± 0.02ab	0.72 ± 0.05a	7.6 ± 0.2a	0.71 ± 0.04a
9		2162 ± 699c	0 ± 2c	0.52 ± 0.04c	0.67 ± 0.01ab	6.7 ± 0.2ab	0.63 ± 0.02ab
12		3566 ± 82b	3 ± 1c	0.55 ± 0.06bc	0.64 ± 0.05abc	7.8 ± 0.8a	0.58 ± 0.02b
18		5100 ± 889a	NA	0.39 ± 0.07d	0.60 ± 0.06bc	7.7 ± 0.4a	0.64 ± 0.04ab
24		4260 ± 668ab	NA	0.49 ± 0.03cd	0.56 ± 0.03bc	6.5 ± 0.4b	0.72 ± 0.08a
30		5001 ± 90a	1 ± 1c	0.49 ± 0.02cd	0.61 ± 0.04bc	7.0 ± 0.5ab	0.49 ± 0.02c
36		4632 ± 273ab	2 ± 3c	0.47 ± 0.04cd	0.52 ± 0.05c	7.2 ± 0.2ab	0.56 ± 0.04bc
38°C							
3	–4°†	3882 ± 120b	16 ± 2a	0.69 ± 0.04a	0.59 ± 0.02	7.8 ± 0.4a	0.70 ± 0.04
3		3509 ± 218bc	3 ± 2bc	0.46 ± 0.09b	0.57 ± 0.03	7.4 ± 0.4ab	0.62 ± 0.04
6		4758 ± 280a	-2 ± 1c	0.36 ± 0.02c	0.70 ± 0.02	7.0 ± 0.3bc	0.60 ± 0.08
9		2620 ± 737c	2 ± 3bc	0.26 ± 0.03d	0.57 ± 0.05	6.7 ± 0.1c	0.53 ± 0.08
12		3402 ± 388bc	4 ± 3b	0.25 ± 0.01d	0.65 ± 0.09	7.0 ± 0.2bc	0.61 ± 0.05

*An Analysis of variance was performed at each temperature. Means followed by different letters are significantly different ($p < 0.05$) as determined by Newman Keuls Multiple Range Test.

†The values at 3 mo. 4°C are substituted as the initial values.

NA = Not Analyzed

Table 8 provides the mean differences (on a moisture-free basis) obtained by correcting the values of the fortified fruitcake for the vitamin content of the unfortified fruitcake. Examination of the mean initial levels of riboflevin, niacin and pyridoxine for both the fortified and unfortified fruitcake (Table 6 and 7) show them to be lower than the levels found in corresponding samples stored 3 months or longer. To correct for these apparently anomalous results (which were even more pronounced on a moisture-free basis), the analytical values for the samples stored 3 months at 4°C were substituted for the initial values in Table 8. In spite of this adjustment, the data in Table 8 fluctuate. This may be attributed to lack of homogeneity in the product rather than to time or temperature effects.

The ascorbic acid data in Table 8 are at the minimum detection limit of the analytical method. At this level (2–3 mg ascorbic acid) the error estimate for a product like fruitcake – which requires grinding with water for uniformity – can be + 100 percent. This fact precluded analysis of the Table 8 ascorbic acid data.

REGRESSION ANALYSES

Figures 2 through 6 show the regression curves for vitamin fortification (excluding ascorbic acid) on the corrected difference data. This data was analyzed on a moisture-free basis from Table 8 at the various storage periods and temperatures. Table 9 summarizes Figures 2 through 6 indicating percent vitamin retention at 4°C and 21°C for three years and 38°C for one year.

Table 9. Projected Retention of Vitamins in Fruitcake After Storage (derived from Figures 2 through 6)

STORAGE		VITAMINS PERCENT				
time months	temperature °C	A	Thiamin	Riboflavin	Niacin	Pyridoxine
36	4	147	91	107	98	85
36	21	138	69	85	93	80
12	38	81	31	108	88	84

Note: The projected percent retention reflects the difference between the initial and final points on each regression curve (Figures 2 through 6).

Vitamin A (Figure 2)

The standard deviations are indicated for vitamin A only since these are variable and frequently quite large. The increased levels of vitamin A found following storage at 4°C and 21°C, + 47 percent and + 38 percent respectively, were not expected. The fact that the results followed a similar pattern at these temperetures leads one to suspect the problem lies in sample preparation and/or analyses. However, the uniformity of proximate, fatty acid and other vitamin data do not support an assumption that the variation in vitamin A content is

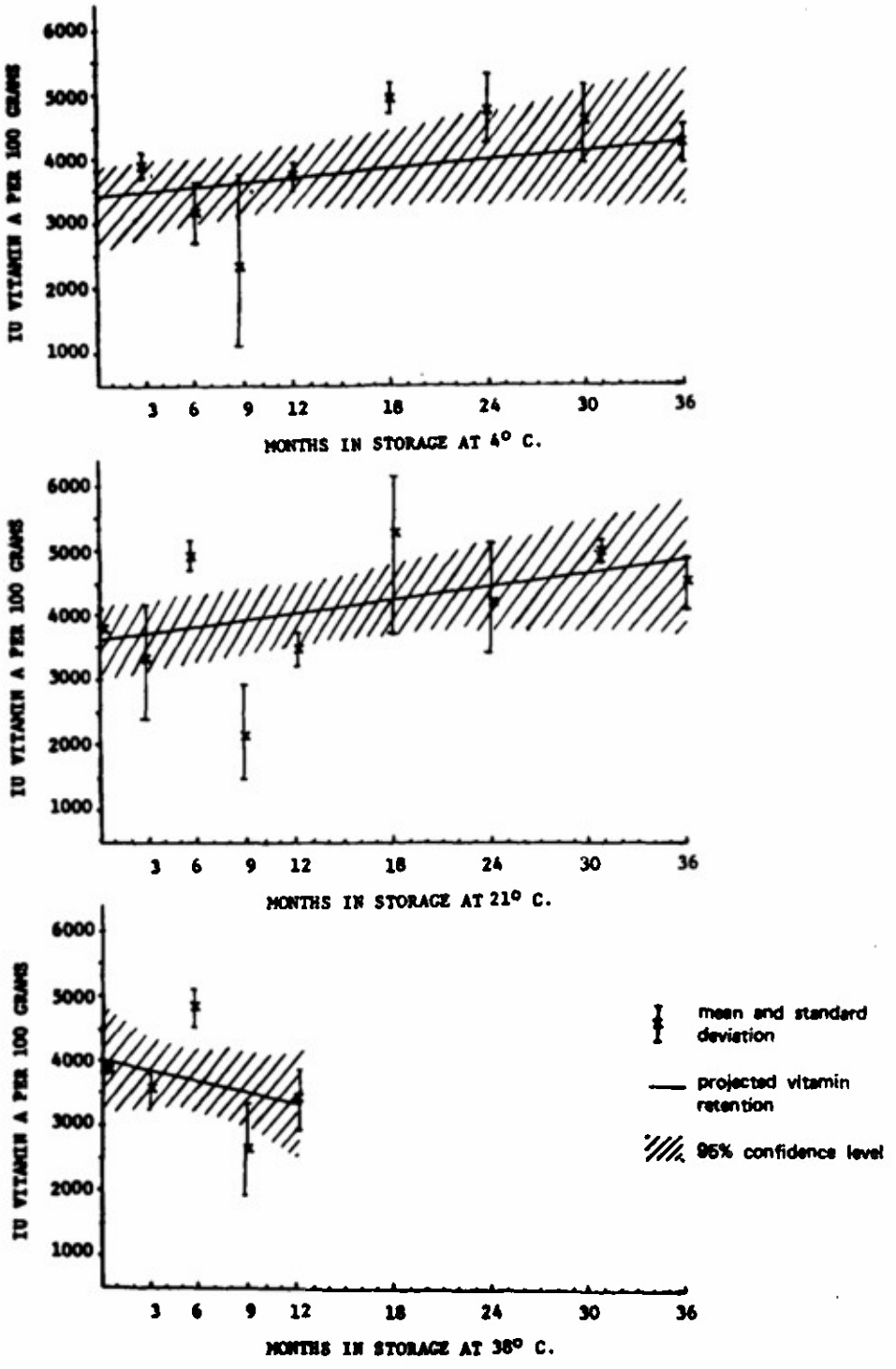


Figure 2. **Regression Curves for Vitamin A differences between Fortified and Unfortified Fruitcake on a moisture-free basis 4°, 21° and 38°C**

totally due to incomplete mixing although it may be a contributing factor. It must also be recognized that vitamin A analysis of mixtures such as fruitcake is difficult. Since the detectable limits of the method are ± 100 I.U., standard deviations of 200 to 300 I.U. are not considered unusual in a nonhomogenous mixture such as fruitcake.

The vitamin A retention of 148 percent for product stored at 4°C, and 138 percent for product stored at 21°C are significant ($P < 0.05$). The reasons for these increases are not known. However, these increases could reflect; (1) differences due to procedures, (2) changes in personnel, (3) possible existence of inhibiting agents in the product which may initially alter measurement of the vitamin and disappear with storage, or (4) the development of an interfering compound in storage that results in an apparent increase and may even mask a decrease of the vitamin during storage. The decrease of 18 percent for product stored at 38°C is not statistically significant. From the data obtained, it is considered that vitamin A is stable. However, the vitamin A level added to fruitcake could be reduced four-fold and 700 grams of product would still provide RDA requirements.

Thiamin (Figure 3)

Thiamin losses following three years storage at 4°C and 21°C are, respectivaly, 9 percent (not significant) and 13 percent (significant at $P < 0.05$), when compared to the initial value. During storage at 38°C, the projected losses (significant at $P < 0.05$) are: 17 percent after 3 months, 35 percent after 6 months and 69 percent after one year. Even so, 700 grams of fortified fruitcake stored one year at 38°C meets the 1968 (and 1980) RDA for thiamin.

Riboflavin (Figure 4)

The increased retentions of riboflavin in product stored at 4°C (± 8 percent) and at 38°C (± 7 percent) are not statistically significant. The change of 15 percent during storage at 21°C is significant ($P < 0.05$). Riboflavin is normally stable during storage even at elevated temperatures.

Niacin (Figure 5)

The losses in niacin content after three years storage at 4°C and 21°C are 2 and 7 percent, respectively, and are not statistically significant. The projected loss of 12 percent following storage for one year at 38°C, while statistically significant ($P < 0.05$), is not large and is indicative of good stability for niacin.

Pyridoxine (Figure 6)

The projected loss in pyridoxine following three years storage at 4°C and 21°C is 15 percent (not significant) and 20 percent, statistically significant, ($P < 0.05$), respectivaly. The loss of 16 percent after one year at 38°C is also significant ($P < 0.05$). However, none of these changes are great and pyridoxine is considered stable in fruitcake at the level added.

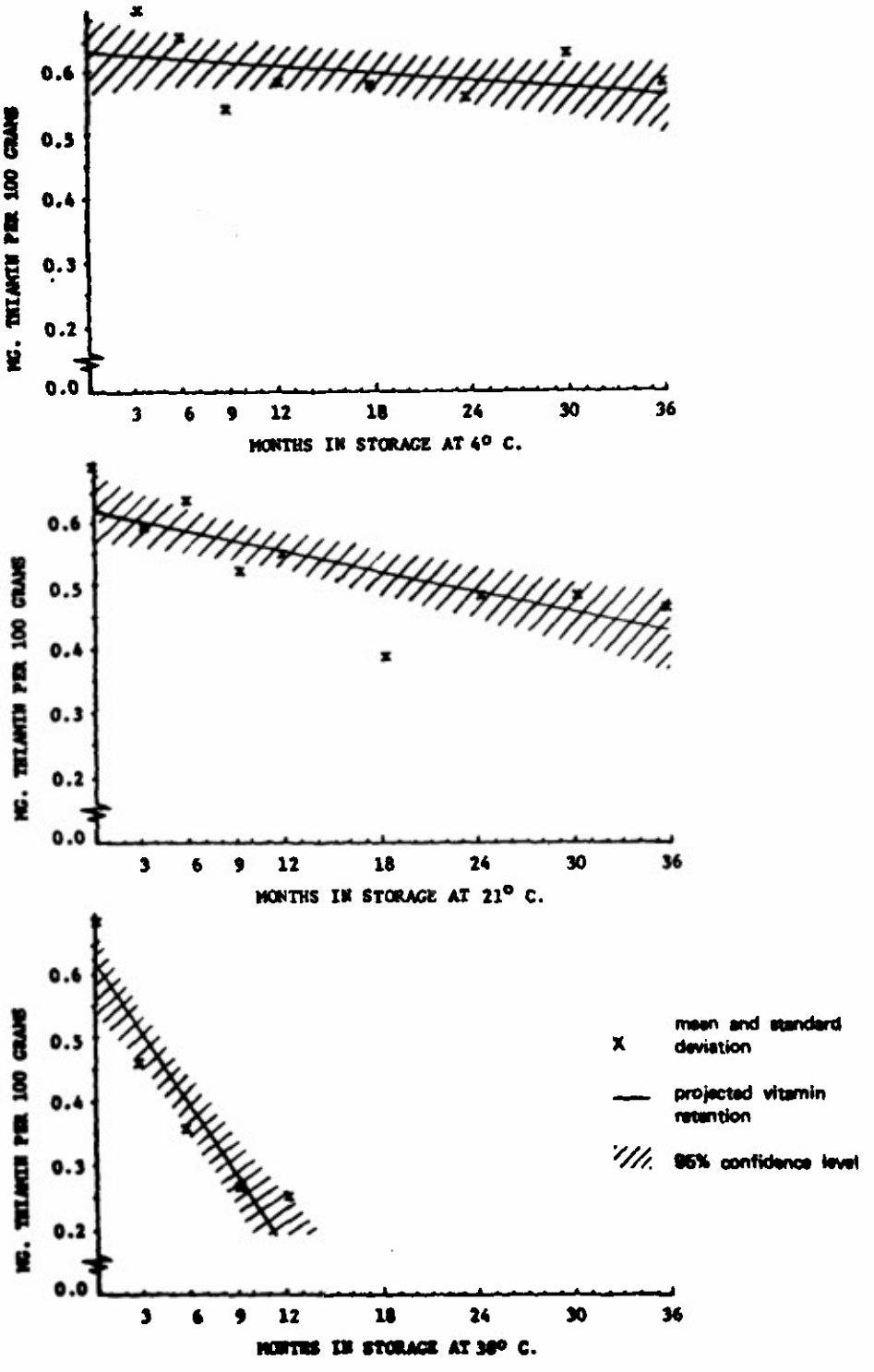


Figure 3. Regression Curves for Thiamin difference between Fortified and Unfortified Fruitcake on a moisture-free basis 4°, 21° and 38°C

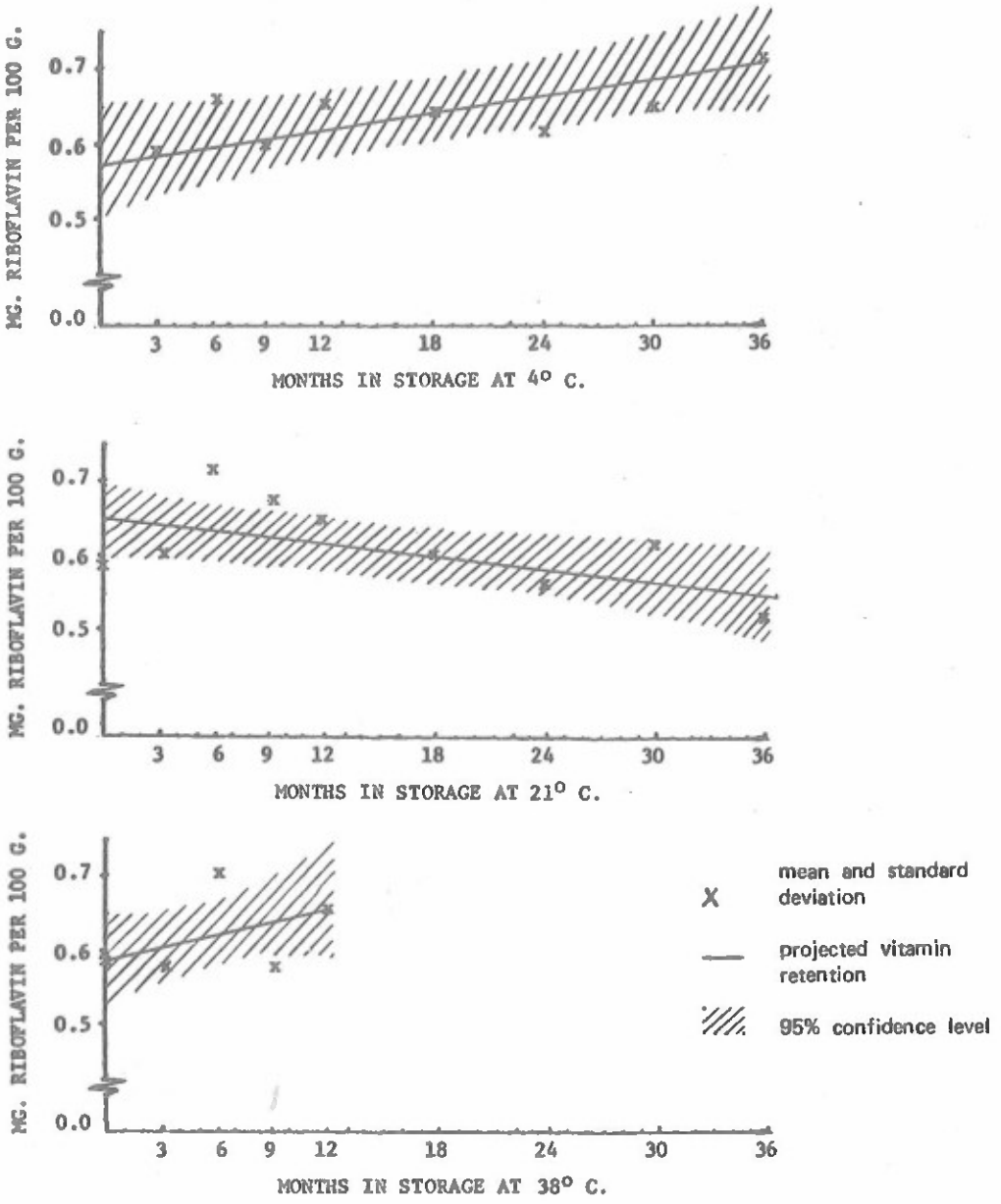


Figure 4. Regression Curves for Riboflavin differences between Fortified and Unfortified Fruitcake on a moisture-free basis 4°, 21° and 38°C

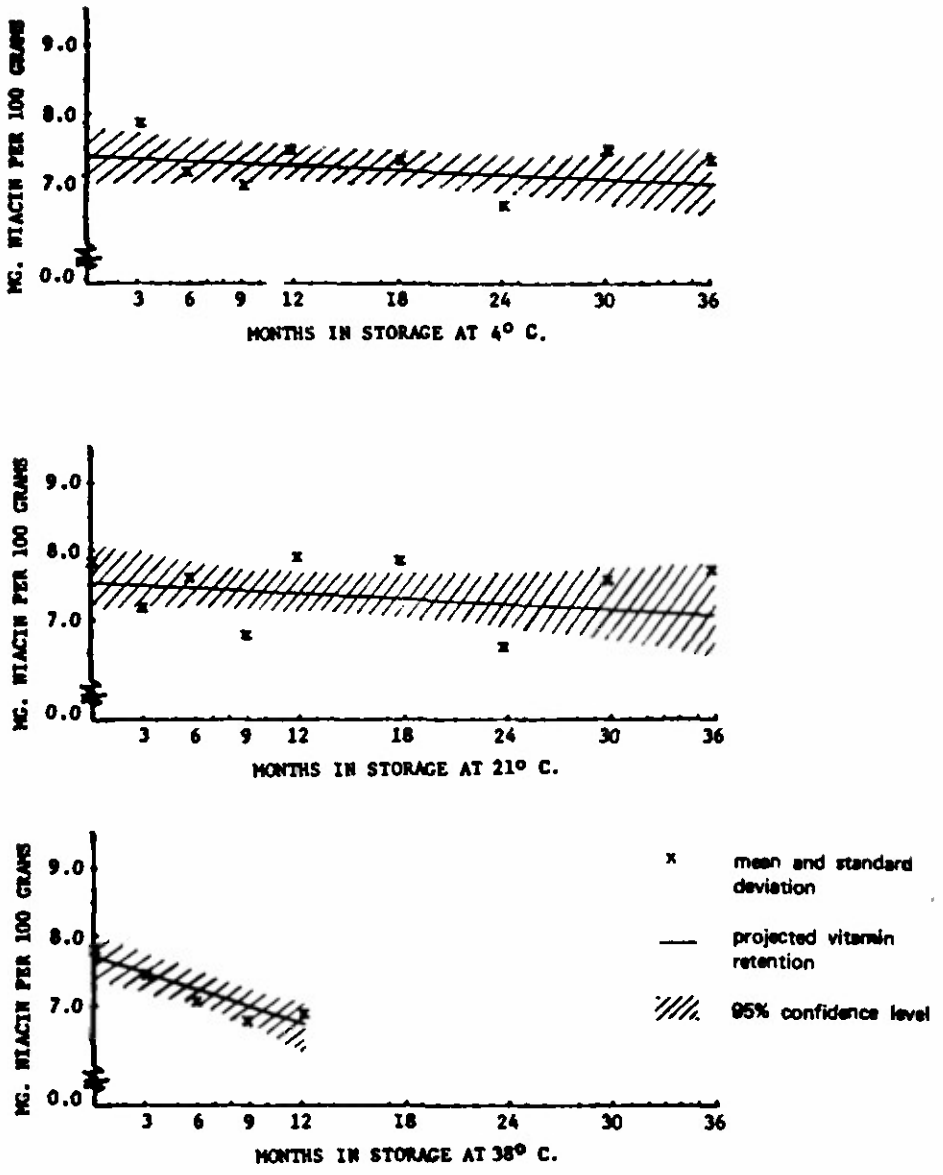


Figure 5. Regression Curves for Niacin differences between Fortified and Unfortified Fruitcake on a moisture-free basis 4°, 21° and 38°C

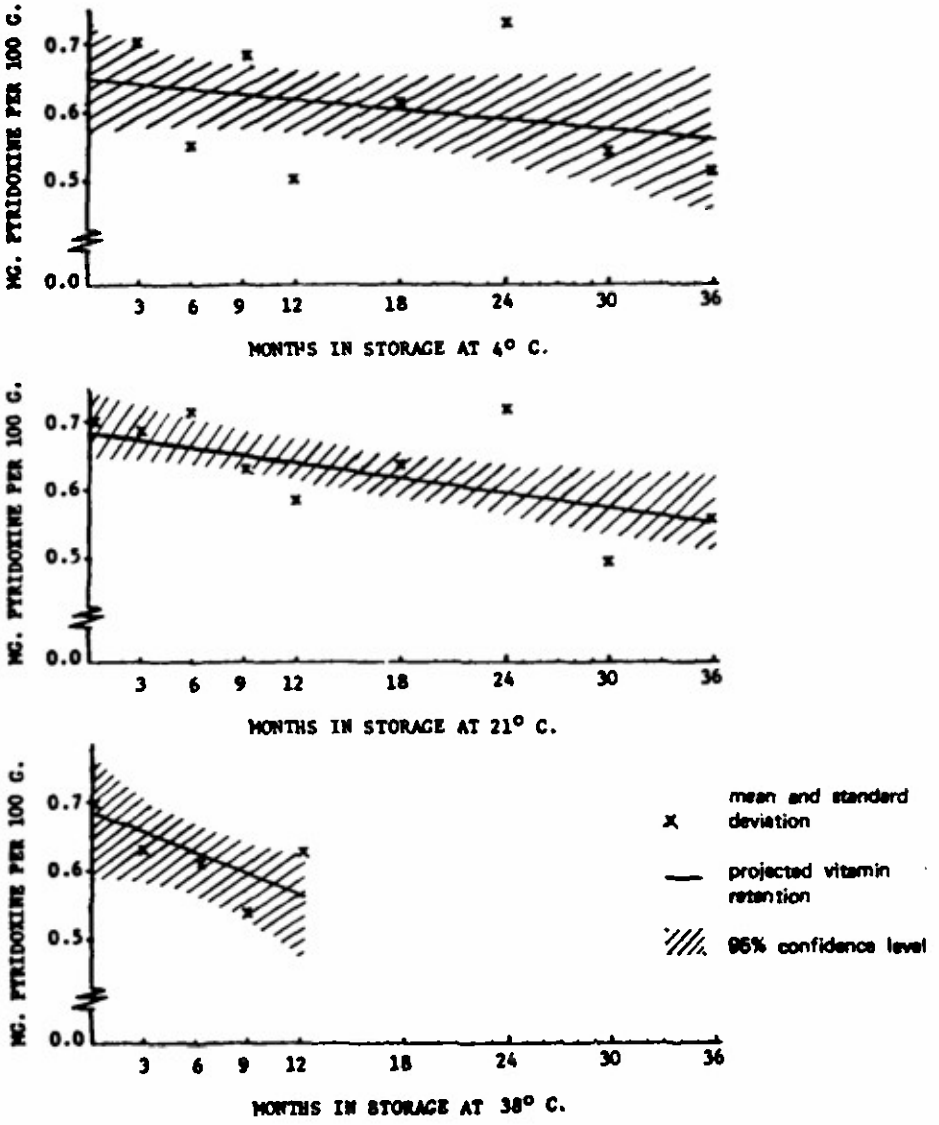


Figure 8. Regression Curves for Pyridoxine differences between Fortified and Unfortified Fruitcake on a moisture-free basis 4°, 21° and 38°C

MULTIPLE REGRESSION ANALYSIS

Appendix C outlines the procedure for the Multiple regression anelysis performed to obtain the correlation coefficents on a "wet-basis" for vitamin data obtained on both the fortified and unfortified fruitcake. Table 10 provides the correlation coefficients obtained from this analysis.

Seventeen of the 30 r-values were non-zero with confidence exceeding 95 percent. Of the non-zero values, 13 were negative indicating a decrease in nutrients, and four were positive. These four r-velues are anomelous since reference to other reports supports the conclusion that these nutrients do not increase during storage. The fortified velues which increased were vitamin A at 4°C and 21°C and riboflavin at 4°C. Further enelyses were made in these cases with the eid of the iteretively-reweighted least-squeres progrem (IRLS), which is part of the collection of programs obtained from the Internetionel Methematical and Statistical Library.[5] This program produces e least-squara fit in which outlying points exert less influence than usuel, end the conclusions are therefore, more stable or robust. When this progrem was used on these four cases, the conclusions were the same, thet is, the four positive r-values showed the nutrient increasing with time of storege.

Scrutiny of the plotted dete reveeled thet in quite e few cases the nutrient decreased repidly up to about 12 months of storage, then at 18 months. jumped up to or ebove the initiel value and thereafter decreased slowly. This was particulerly evident for vitamin A et 4°C and 21°C.

CONCLUSIONS

1. Tha concept of using fortified fruitcake as e single food contingency ration is sound.

2. Fruitcake in e 700-gram quentity meets NASA's requirement for e 2800-calorie contingency ration. Production using e 50/50 retio of soy end wheet flour assures compliance with NASA's requirement of 7 to 8 percent of total celories as protein. Fifty six grams of protain (100 percent of the 1980 RDA) ere supplied in 100 grems of fruitcake.

3. Thermoprocessed flexibly packaged fruitceke, fortified with minerals (calcium and magnesium) and vitamins (A, thiemin, riboflevin, niacin and pyridoxine), meets NASA's stability requirements of providing RDA levels of nutrients, and remelning acceptable throughout three years ambient storege (21°C) end withstending short time exposure to 38°C.

4. The fortified fruitceke developed by NLA8S fer exceeded NASA's high tempereture stability requirements, retaining acceptability and meeting RDA nutrient requiremants throughout one year's storage at 38°C.

[5] See reference 4.

Table 10. Comparison of Correlation Coefficients from Fortified and Unfortified Fruitcake Vitamins

Vitamin	Sample Type	Storage Temperature 4°C	21°C	38°C
A	Fortified	+ 0.507*	+ 0.461*	- 0.237
	Unfortified	- 0.251	+ 0.028	- 0.823
Thiamin	Fortified	- 0.379	- 0.677	- 0.927
	Unfortified	- 0.012	- 0.491	+ 0.950
Riboflavin	Fortified	+ 0.281*	- 0.502	+ 0.037
	Unfortified	- 0.065	- 0.395	- 0.458
Niacin	Fortified	- 0.014	- 0.072	- 0.490
	Unfortified	+ 0.773	-.522*	- 0.438
Pyridoxine	Fortified	- 0.167	- 0.221	+ 0.044
	Unfortified	- 0.361	- 0.190	- 0.462
T_C = critical T at 95 percent confidence level		± 0.271	± 0.271	± 0.355

NOTES: Underlined values are Non-zero at 95 percent confidence level.

Asterisks denote results where the nutrient was found to increase with time.

T_C = + 0.298 at 95 percent confidence level, P = 0.05.

5. Throughout tha storage study, consumer panals gave fortified and control (unfortified) fruitcakes equivalent acceptance ratings.

6. Thermoprocessed flexibly packaged fruitcake, receiving a "like moderately" hedonic rating at zero tima, will drop one scala point to "like slightly" after three years at 4°C and 21°C or six months at 38°C. It will drop approximately two hedonic scale points to "neither like nor dislike" after 12 months at 38°C.

7. The level of vitamin A supplied in 700 grams of fortified fruitcake was too high throughout the study, being four times the RDA (5000 I.U.) even after one year at 38°C. The demonstrated stability of Vitamin A added at four-fold tha needed level cannot be extrapolated accurately to predict stability at one-fourth this level.

8. Losses of ascorbic acid during processing (87 percent) prevented assessment of the stability of ascorbic acid in fruitcake. A two-fold increase in ascorbic acid is needed to compensate for processing losses. The data indicate that storage losses may occur, but the extent of such losses cannot be estimated. Even though ascorbic acid may prove unstable, its addition is recommended in view of the protective effect it provides other nutrients.

RECOMMENDATIONS

1. To assure that fruitcake is nutritionally complete (meets RDA), it is recommended that the nutritional phase of this study be repeated to:

   a. Assess the stability of vitamin A when fortification level is reduced to one-fourth.

   b. Increase the level of ascorbic acid and determine losses during storage.

   c. Confirm that when calcium fortification is doubled the RDA is met.

   d. Determine the stability of the vitamins not covered in this study (B_{12}, E, and Folic Acid).

   e. Determine zinc content of fruitcake (the 1980 RDA requirement is 15 mg).

2. It is further recommended that fortified cake-type product be considered for military ration use. It appears to have potential as a fortified ration component or as a single food supplement for use under conditions when it is desirable to boost calories but not protein and sodium levels. Fortified fruitcake meets the General Purpose Survival Food Packet nutritional criteria, however, its stability at 60°C is unknown.

This document reports research undertakan at the US Army Natick Research and Development Command and has been assigned No. NATICK/TR-82/004 in the series of reports approved for publication.

APPENDIXES

A Space Food Prototype Production Guide No. 58

B Methods of Analyses

C Procedure for Multiple Regression Analysis

APPENDIX A

Space Food Prototype
Production Guide No. 58
U.S. Army Natick Laboratories
Natick, Massachusetts
30 August 1972

FRUITCAKE, THERMOPROCESSED, FLEXIBLY PACKAGED UNDER VACUUM

1. SCOPE

1.1 Scope - This production guide covers the requirements for preparation of thermoprocessed high protein fruitcake for use in aerospace feeding.

1.1.1 Size of product

a. 3 oz package

b. 6 oz package

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this production guide to the extent specified herein:

STANDARDS

Federal

Federal Test Method - Plastics: Methods of Testing Standard No. 406

NASA PRODUCTION GUIDES

Space Food Prototype Production Guide Addendum 1E, Microbiological Requirements for Space Food Prototypes

2.2 Other Publications - The following documents form a part of this production guide to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of invitation for bids or request for proposal shall apply:

U.S. Department of Health, Education, and Welfare

Federal Food, Drug and Cosmetic Act and Regulations Promulgated Thereunder.

(Applications for copies should be addressed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)

3. REQUIREMENTS

3.1 Material (all types) - All components and materials shall be clean and free from foreign material, foreign odor, foreign color, and foreign flavor.

3.1.1 Flour - Flour shall be hard or soft wheat of the type known as high ratio cake flour, bleached, enriched or unenriched. If unenriched is used, equivalent enrichment shall be incorporated.

3.1.2 Flour, soy - Soy flour shall be of the powdered soy type. The protein content shall be 52.5 percent by weight and the fat content shall be no higher than 4 percent by weight.

3.1.3 Sugar - Sugar shall be granulated, refined cane or beet sugar, or a combination of both.

3.1.4 Shortening - Shortening shall be refined, hydrogenated cottonseed or peanut oil or a combination of both, and shall have a stability of not less than 100 hours as determined by the Active Oxygen Method (AOM). Soy oil shall not be used.

3.1.5 Eggs - The eggs shall be fresh shell eggs.

3.1.6 Salt - Salt shall be white, refined sodium chloride with or without an anticaking agent. Iodized salt shall not be used.

3.1.7 Baking powder - Baking powder shall be free flowing and of a type which will result in the production of the required end product.

3.1.8 Cherries, candied - Candied cherries shall be sweet, pitted and thoroughly processed with sugar to 75 percent soluble solids and shall be flavored with wild cherry flavor. The whole cherries shall be cut into halves.

3.1.9 Pineapple, candied - Pineapple shall be thoroughly processed with sugar to 75 percent soluble solids. The pineapple pieces shall be cut to approximately 1/4 inch dice.

3.1.10 Nuts - Nuts shall be pecan pieces and shall conform to the standard for U.S. No. 1 pecan pieces, small pieces as defined in U.S. Standards for Grades of Shelled Pecans or Almonds.

3.1.11 Raisins - Raisins shall be bleached Thompson seedless, select size, grade B or better, as defined in the United States Standards for Grades of Processed Raisins.

3.1.12 Spices - Spices used shall be powdered, free flowing and of a pleasant aroma, readily suggestive of the required type.

3.2 Formula

	% by weight
Flour, wheat, soft	7.3
Flour, soy	7.3
Sugar	19.0
Shortening	7.8
Eggs, whole, fresh	6.96
Salt	.4
Baking powder	.4
Water	2.2
Cherries, candied	10.4
Pineapple, candied	8.6
Pecans, shelled	13.8
Raisins, bleached	15.6
Clove powder	.06
Nutmeg	.06
Cinnamon	.12
	100.00

3.3 Preparation

3.3.1 Mixing

a. Blend all dry ingredients, except sugar. Set aside.
b. Cream sugar and shortening until well mixed.
c. Add whole eggs and mix thoroughly on medium speed.
d. Add 50 percent of the dry ingredients and 50 percent of the water. Mix until well blended.
e. Add the remainder of dry ingredients and water. Mix well.
f. Mix in fruit and nuts at low speed until blended.

3.3.2 Filling and sealing - The fruitcake batter shall be filled and sealed in flexible containers (see 5.1) without the product contacting the inside of the flexible container at any point which will subsequently be sealed. Components shall be filled in the following proportions and the containers heat sealed (see 5.1.2). Three ounces or six ounces of fruitcake batter (as specified) shall be filled into the appropriate flexible container (see 5.1) and heat sealed (see 5.1.2).

3.3.3 Thermoprocessing - The filled and sealed flexible containers shall be thermally processed in a retort equipped with racks or dividers which provide physical separation of the pouches to insure uniform heat penetration into each package. The racks or dividers shall be free from burrs and sharp edges and shall essentially immobilize the pouches and maintain approximately 1/2-inch separation between pouches. Sufficient and closely controlled overriding pressure shall be maintained to prevent straining of the pouch seals during processing. Pouches shall be processed for 15 minutes at 250°F. Provisions shall be made to assure uniform and equal heating of all pouches in each retort batch. After thermoprocessing, pouches shall be cooled and dried. Pouches that show evidence of delamination, blistering of the packaging material components, occluded matter in the closure seal area, wrinkled or incomplete seals, or evidence of product leakage shall be removed and excluded.

3.3.4 Vacuum packaging and pasteurization - The cooled fruitcake shall be carefully transferred to a second flexible package (see 5.1.2) which will be subsequently sealed under not less than 28 inches of Mercury. After sealing the pouches of vacuum packaged fruitcake shall be pasteurized for 10 minutes at 176°F.

3.4 Finished product - The finished product shall comply with the requirements of table I and 3.4.1.

TABLE I - Finished Product Requirements

Item Number	Requirement
1	There shall be no foreign odor, flavor, or color such as but not limited to burnt, scorched, stale, rancid, musty or moldy odor.
2	There shall be no foreign material such as but not limited to dirt, insect, insect part, wood, paper, paint, glass or metal.
3	There shall be no foreign color.
4	The product shall conform to the following weights: a. 3 ounces ± 1/8 ounce b. 6 ounces ± 1/8 ounce

TABLE I - Finished Product Requirements (cont'd)

Item Number	Requirement
5	The product shall have an acceptable flavor.
6	After vacuum packaging product shall be practically free of crumbs.

3.4.1 Microbiological procedures shall be in accordance with 4.3.

4. TESTS

4.1 Seal atrength test - Seal strengths ahall be tested in accordance with the procedure specified in Method B of ASTM Designation D882-64T (Method 1013 of Federal Test Method Standard No. 406, Method B). Seal specimens shall be 1/2-inch in width and shall be pulled at a uniform rate of 10-inches per minute. Readings ahall record tensile strength at time of seal break. One specimen shall be taken from each of the three manufacturer's seals of bags tested. The average results from the three specimens shall represent the seal strength of the bag tested. The seal strength of the package's closure shall be the average of two non-adjacent apecimens.

4.2 Vacuum cycling test - Pouches shall be placed in a chamber and the chamber shall be cycled from atmospheric to 10^{-6} torr six times. Any evidence of product leakage, bursting of the package, or delamination of the packaging material shall be considered failure.

4.3 Microbiological test

4.3.1 Requirements - See Space Food Prototype Production Guide Addendum 1E.

4.3.2 Method - The finished product shall be tested for the microbiological requirementa in accordance with Addendum 1E.

5. PREPARATION FOR DELIVERY

5.1 Packaging - After preparation (see 3.4.1) the product shall be filled in accordance with 3.2.2 into flexible container complying with 5.1.1 and be sealed in accordance with 5.1.2.

5.1.1 Packaging Materials - The flexible containers shall be fabricated from a laminated barrier material conaisting of 0.0005-inch thick polyester-0.00035-inch thick aluminum foil - 0.003-inch thick polyolefin. The material shall be suitably formulated for heat retorting and ahall be capable of withstanding exposure to 240°F. steam or water for 60 minutes and 250°F. steam or water for 30 minutes without delamination or degradation. The material shall meet the requirements of Section 121.2514, Condition of Use A, of the Federal Food, Drug and Cosmetic Act and Regulations Promulgated Thereunder and shall not impart flavor or odor foreign to the product packaged.

5.1.2 Package formation and closure - The pouches shall be made by heat sealing the sides and bottom with seals 3/8-inch ± 1/8-inch wide to form the sizes of pouches specified below:

First pouch for retorting:

6 oz product - 4-1/2 x 7 ± 1/8 inch
3 oz product - 4-1/2 x 5-1/2 ± 1/8 inch

Second pouch for vacuum packaging:

6 oz product - 4-3/4 x 8-1/4 ± 1/8 inch
3 oz product - 4-3/4 x 5-1/2 ± 1/8 inch

Seal strength shall be not less than 12 pounds per inch of width when tested in accordance with 4.1. The pouch opening shall be in one of the edges with the smaller dimension. Closure shall be effected by means of a heat seal 3/8-inch ± 1/8-inch wide. Care in filling and sealing shall be exercised to prevent any wrinkles in the seal which may impair maintenance of a hermetic seal. Seal strength of the closure seal shall be not less than 12 pounds per inch width when tested in accordance with 4.1. Pouches shall pass the vacuum cycling test of 4.2. Headspace gases shall be removed by vacuum sealing of the second pouch at not less than 28" of Mercury.

5.2 Labeling, Packing and Marking - Shall be as specified by NASA.

5.2.1 Labeling - The following information shall appear on a label glued to the package:

a. Name of the product
b. New weight
c. Date of manufacture
d. Name of manufacturer
e. Lot number

5.2.2 Marking - The following information shall appear on a label or be marked on the box:

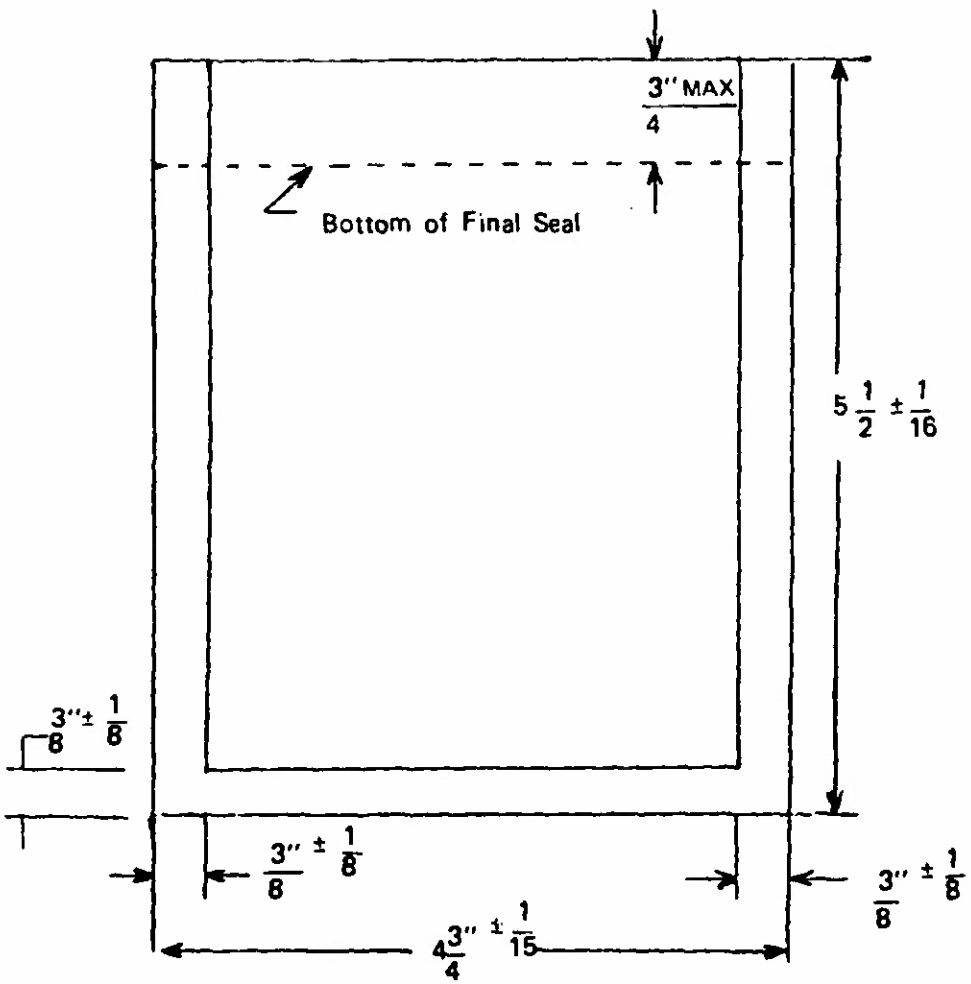
a. Name and address of addressee
b. Name and address of addressor
c. An attention line
d. The words FRAGILE OR HANDLE WITH CARE

6. NOTES

6.1 Ordering Data - Purchasers should exercise any desired options offered herein and procurement documents should specify the following:

a. Title, number and date of this document
b. Size required - 3 oz or 6 oz portion

Pouch – 3 Ounce Fruitcake



APPENDIX B

METHODS OF ANALYSES

AOAC Methods, Thirteenth Edition (1980)

Assay	Reference
Moisture	As appropriate
Total Fat	As appropriate
Protein	2.057
Crude Fiber	7.065
Ash	14.006
Phosphorus	2.021
Chloride as NaCl	18.034
Cholesterol	14.149
Fatty Acid Profile	28.051
Total Fatty Acids	
Atomic Absorption Spectrophotometer	AASP[1]
Calcium	AASP
Iron	AASP
Sodium	AASP
Potassium	AASP
Magnesium	AASP
Other	
Iodine	Anal. Chimica Acta 10, 78 (1954)

Methods of Vitamin Assay - Third Edition (1966)

Assay	Pages
Vitamin A	70-79
Carotene	104-115
Thiamin	127-140
Riboflavin	158-164
Niacin	172-176
Pyridoxine	212-219
Vitamin E[2]	366-396
Ascorbic Acid	299-306
Folacin	227-234
Vitamin B_{12}	262-270

[1]Atomic absorption spectrophotometry methods are based upon solution of ash in acid followed by dilution and reading. In the case of calcium and magnesium a further step is required in that lanthanum salt is added before spectrophotometry. The general procedures are described in "Analytical Methods for Atomic Absorption Spectrophotometry", Perkin-Elmer, 1964.

[2]Acta Chem. Scand. 11, 34 (1957)
J. Chromato. 27, 96 (1967)

APPENDIX C

Procedure for Multiple Regression Analysis

The known independent variables in this study were:

T = time of storage in months (0, 3, 6, 9, 12, 18, 24, 30, 36)

H = temperature of storage (4, 21, 38, celcium)

F = degree of fortification (0, 1) i.e. (no fortification, fortification)

The dependent variables were the nutrients

A = vitamin A

N = Niacin

P = pyridoxine

R = riboflavin

Th = thiamin

We are concerned with the dependence of the nutrients on T as functions of H and F. We anticipate that the dependence might assume the linear form as $A = A_0 + A_1 T$. Where A_0 and A_1 do not depend on T but may depend on H and F.

The experimental data consisted of six replications for each nutrient at each of the following conditions:

H = 4°, F = 0 T = 0, 3, 6, 9, 12, 18, 24, 30, 36

F = 1

H = 21°, F = 0

F = 1

H = 38°, F = 0 T = 0, 3, 6, 9, 12

F = 1

The data for each nutrient as a function of T were first plotted, and simple, linear, least-squares fits were carried out at each of the five test conditions: H = 40, 70, 100, and F = 0. The results for the correlation coefficient r, obtained from graphs (Figures 2 to 6) are listed in Table 10.